

WHAT IS CLAIMED IS:

1. A method for tracking ectopic beats through template matching, comprising the steps of:

- (a) capturing a first ECG signal in a signal processing unit;
- 5 (b) permitting a user to mark a begin point and an end point of the captured first ECG signal;
- (c) defining a reference template as being a waveform segment between the marked begin and end points of the first ECG signal;
- (d) acquiring data at the signal processing unit; and
- 10 (e) using a correlation coefficient calculation on the acquired data to identify a best fit between the reference template and the acquired data.

2. The method of claim 1, wherein the acquired data is acquired across multiple leads at a given point in time and is provided either from a data storage device or from a real-
15 time data stream.

3. The method of claim 2, including the additional step of aligning on a display an image of the reference template with a beat within the acquired data across the multiple leads so as to display the extent of the identified best fit of the reference template with the acquired data
20 from each of the multiple leads.

4. The method of claim 1, including the additional step of outputting a quantitative indicator of the correlation coefficient calculation.

5. The method of claim 4, wherein the data is acquired from multiple leads and wherein the quantitative indicator is a composite average of coefficients calculated from the multiple leads.

6. The method of claim 5, wherein the quantitative indicator is displayed as a graph showing percentage of fit.

7. The method of claim 1, wherein the reference template is a segment of a spontaneous beat and wherein the acquired data is a paced beat.

8. The method of claim 1, wherein the reference template is a segment of a first spontaneous beat and wherein the acquired data is a second spontaneous beat which is different than the first spontaneous beat.

9. The method of claim 1, wherein the acquired data is from a real-time data stream, the method including the additional step of repeating the correlation coefficient calculation on the acquired data at a prescribed interval.

10. A method for deriving a p-wave signal from a premature atrial contraction ("PAC") beat to assist a person in diagnosing a heart, comprising the steps of:

- (a) selecting a QRS-T segment of a reference ECG signal;
- (b) permitting a user to mark a begin point and an end point of the selected
5 segment of the reference ECG signal;
- (c) defining a reference template as being a waveform segment between the marked begin and end points of the selected segment of the reference ECG signal;
- (d) acquiring the PAC beat at the signal processing unit from multiple leads;
- and
- 10 (e) processing the PAC beat so as to derive the p-wave signal.

11. The method of claim 10, wherein the processing step comprises subtracting the reference template from a predetermined segment of the PAC beat.

15 12. The method of claim 10, wherein the reference ECG signal is a single beat.

13. The method of claim 10, wherein the reference ECG signal is a signal derived from an average of multiple beats.

20 14. The method of claim 10, wherein the reference ECG signal is a beat that immediately precedes the PAC beat.

15. The method of claim 10, including the additional step of synchronizing the reference template and the PAC beat by aligning respective waveform segments thereof.

5 16. The method of claim 15, wherein the alignment is by using a correlation coefficient calculation on the acquired data to identify a best fit between the respective waveform segments.

10 17. The method of claim 15, wherein the respective waveform segments are the QRS complexes of the reference template and the PAC beat.

18. The method of claim 17, wherein the alignment is by using a correlation coefficient calculation on the PAC beat to identify a best fit between the QRS complexes of the reference template and the PAC beat.

15 19. The method of claim 16, including the additional step of permitting the person to shift the alignment thereby causing a change in the correlation coefficient calculation

20 20. The method of claim 16, including the additional step of permitting the person to shift the reference template to a waveform segment between corresponding begin and end points of a different beat thereby causing a change in the correlation coefficient calculation

21. The method of claim 10, including the additional steps of:

repeating the acquiring and processing steps so as to derive p-waves from at least two
different PAC beats, and

5 comparing the derived p-waves to one another.

22. The method of claim 21, wherein the comparing step comprises performing a
cross correlation waveform analysis.

10 23. The method of claim 21, including the additional step of selectively indicating on
an output device a quality of a match as a function of the comparing step to thereby provide an
indicator as to whether the derived p-waves have the same focal origin.

24. The method of claim 10, including the additional steps of comparing the derived
15 p-wave to a library of p-waves of known focal origin, and predicting the most likely site of the
origin as a function of the comparison.

25. The method of claim 10, wherein the derived p-wave is a derived, spontaneous p-
wave, the method including the additional steps of maneuvering a pace mapping catheter within
20 or adjacent the atria while pacing the heart while repeating the acquiring and processing steps so

as to derive a paced p-wave, and comparing the derived, paced p-wave to the derived, spontaneous p-wave.

26. The method of claim 10, including the additional step of determining an integral
5 value of the area of the derived p-wave signal.

27. The method of claim 26, including the additional step of normalizing the integral
value over a length of the derived p-wave signal.

10 28. The method of claim 27, wherein the marked beginning and end points define a
QRS segment of the reference ECG signal, the method including the additional step of
measuring the QRS residue of the derived p-wave signal to provide an indicator of the alignment
quality between the QRS segment of the PAC beat and a QRS segment of the reference template.

15 29. The method of claim 28, wherein the processing step comprises subtracting the
reference template from the QRS segment of the PAC beat, and wherein the QRS residue is an
integral value computed after the processing step.

20 30. The method as in claim 10, wherein the acquiring and processing steps are
repeated, the method including the additional steps of:

calculating, for each iteration of the acquiring and processing steps, the integral value of the QRS segment of the reference template and the integral value of the PAC beat,

determining any change in absolute peak value percentage of the integral values between the reference template and the PAC beat,

5 whereby any baseline drift is identified.

31. A method for deriving a non-synchronous subcomponent from a first heartbeat signal having a composite waveform which includes a synchronous subcomponent overlapping the non-synchronous subcomponent in order to assist a person in diagnosing a heart, comprising the steps of:

10 (a) selecting a synchronous subcomponent of a second heartbeat signal which corresponds to the synchronous subcomponent of the first heartbeat signal;

(b) permitting a user to mark a begin point and an end point of the selected synchronous subcomponent;

15 (c) defining a reference template as being a waveform segment between the marked begin and end points of the selected synchronous subcomponent;

(d) acquiring the composite waveform of the first heartbeat signal at the signal processing unit from multiple leads; and

(e) processing the composite waveform beat so as to derive the non-synchronous subcomponent.

32. The method of claim 31, wherein the processing step comprises subtracting the reference template from a predetermined segment of the composite waveform.

5 33. The method of claim 31, wherein the selected synchronous subcomponent is from a single beat.

34. The method of claim 31, wherein the selected synchronous subcomponent is a signal derived from an average of multiple beats.

10 35. The method of claim 31, wherein the selected synchronous subcomponent is from a beat that immediately precedes the composite waveform.

15 36. The method of claim 31, including the additional step of synchronizing the reference template and the composite waveform by aligning respective synchronous waveform segments thereof.

20 37. The method of claim 36, wherein the alignment is by using a correlation coefficient calculation on the acquired data to identify a best fit between the respective synchronous waveform segments.

38. The method of claim 36, wherein the respective waveform segments are the synchronous subcomponents of the reference template and the composite waveform.

39. The method of claim 38, wherein the alignment is by using a correlation coefficient calculation on the composite waveform to identify a best fit between the synchronous subcomponents of the reference template and the composite waveform.

40. The method of claim 37, including the additional step of permitting the person to shift the alignment thereby causing a change in the correlation coefficient calculation.

41. The method of claim 37, including the additional step of permitting the person to shift the reference template to a waveform segment between corresponding begin and end points of a different heartbeat thereby causing a change in the correlation coefficient calculation.

42. The method of claim 31, including the additional steps of:
repeating the acquiring and processing steps so as to derive non-synchronous subcomponents from at least two different composite waveforms, and
comparing the derived non-synchronous subcomponents to one another.

43. The method of claim 42, wherein the comparing step comprises performing a cross correlation waveform analysis.

44. The method of claim 42, including the additional step of selectively indicating on an output device a quality of a match as a function of the comparing step to thereby provide an indicator as to whether the derived non-synchronous subcomponents have the same focal origin.

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45. The method of claim 31, including the additional steps of comparing the derived non-synchronous subcomponent to a library of non-synchronous subcomponents of known focal origin, and predicting the most likely site of the origin as a function of the comparison.

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46. The method of claim 31, wherein the derived non-synchronous subcomponent is a derived, spontaneous non-synchronous subcomponent, the method including the additional steps of maneuvering a pace mapping catheter within or adjacent the atria while pacing the heart, and repeating the acquiring and processing steps so as to derive a paced non-synchronous subcomponent until such time that the derived paced and spontaneous subcomponents correlate with one another within a prescribed criterion.

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47. The method of claim 31, including the additional step of determining an integral value of the area of the derived non-synchronous subcomponent.

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48. The method of claim 47, including the additional step of normalizing the integral value over a length of the derived non-synchronous subcomponent.

49. The method of claim 31, including the additional steps of
comparing the derived non-synchronous subcomponent to a library of non-
synchronous subcomponents of known focal origin, the derived non-synchronous
5 subcomponent being a spontaneous non-synchronous subcomponent;
predicting the most likely site of the origin as a function of the comparison;
maneuvering a pace mapping catheter within or adjacent the heart while pacing
the heart in real-time;
repeating the acquiring and processing steps so as to derive a paced non-
10 synchronous subcomponent until such time that the derived, paced and spontaneous
subcomponents correlate with one another within a prescribed criterion.

50. A method for locating an ectopic beat during pace-mapping with a roving
catheter, comprising the steps of:

- 15 (a) eliciting at least first and second paced signals from respective first
and second locations of the roving catheter;
- (b) using a correlation coefficient calculation on the elicited first and
second paced signals to identify a best fit between a reference template and each of the
first and second paced signals; and
- 20 (c) simultaneously displaying on a display the best fit for each of the
first and second paced signals.

51. The method of claim 50, whereas the reference template comprises a waveform segment of a single heart signal which includes an arrhythmic component.

5 52. The method of claim 51, further comprising the step of displaying the reference template on the display while the first and second paced signals are being displayed.

10 53. The method of claim 50, including the additional step of displaying a quantitative indicator of each correlation coefficient calculation on the display.

54. The method of claim 50, wherein the data is acquired from multiple leads and wherein the quantitative indicator is a composite average of coefficients calculated from the multiple leads.

15 55. The method of claim 50, wherein the quantitative indicator is displayed as a graph showing percentage of fit.

20 56. A method for tracking ectopic beats through template matching, comprising the steps of:

(a) establishing a reference template over an interval of a first ECG signal;

- (b) monitoring a data signal for a triggering event;
- (c) initiating an offset period in response to the triggering event; and
- (d) after the offset period has elapsed, using a correlation coefficient

calculation on the data signal to identify a best fit between the reference template and the
5 data signal over the interval.

57. The method of claim 56, wherein the triggering event is defined by the
user.

10 58. The method of claim 56, wherein the triggering event comprises one of: a
waveform property, a pacing pulse, an activation sequence, an external timing signal, and
a combination thereof.

15 59. The method of claim 56 wherein the data signal is acquired from a real-
time data stream which includes successive triggering events, the method including the
additional step of repeating steps (c) and (d) in response to each successive triggering
event in the real-time data stream.

20 60. The method of claim 56 wherein the correlation coefficient calculation
terminates upon a designated event.

61. The method of claim 60 wherein the designated event is a correlation coefficient value threshold.

62. The method of claim 56, including the additional step of processing a portion of the data signal corresponding to the identified best fit.

63. The method of claim 62, wherein the processing step comprises subtracting the reference template from the portion of the data signal corresponding to the identified best fit to define a derived waveform, the method including the additional step of displaying the derived waveform on a display.

64. The method of claim 62, wherein the processing step comprises ablating heart tissue.

65. A method for identifying multiple distinct arrhythmias comprising the steps of:

- (a) acquiring a first arrhythmia signal;
- (b) defining the first arrhythmia signal as a first template;
- (c) acquiring a second arrhythmia signal;
- (d) correlating the first template and the second arrhythmia signal;

(e) identifying the second arrhythmia signal as a second, distinct arrhythmia if the correlation fails prescribed criteria.

5 66. The method of claim 65, wherein greater than two arrhythmia signals are present, and comprise a set of templates, the method further comprising the steps of:

(a) defining the second, distinct arrhythmia as a second template;
(b) acquiring an additional arrhythmia signal;
(c) sequentially correlating the additional arrhythmia signal to each template in the set of templates;

10 (d) identifying the additional arrhythmia signal as a distinct arrhythmia signal if the correlation fails prescribed criteria;

(e) defining the additional distinct arrhythmia signal as an additional template and repeating steps (b) - (e) until no additional arrhythmia signals remain that fail the prescribed criteria.

15 67. The method of claim 66, including the additional steps of:

(a) acquiring a paced signal produced by a pace mapping catheter in or adjacent to the heart;

(b) correlating the paced signal sequentially to each of the templates in the set;

20 (c) identifying the location of an ectopic focus when a correlation of the paced signal to one of the templates meets or exceeds prescribed criteria.

68. The method of claim 67, further comprising the step of abating the ectopic focus.

5 69. The method of claim 67, further comprising repeating steps (a) - (c) until the ectopic focus location of each distinct arrhythmia signal has been identified.

70 The method of claim 1 wherein the defining step comprises:
defining the reference template as a set of waveform segments that are obtained from a
10 plurality of electrocardiac leads between marked begin and end points.

71. The method of 70 wherein the begin points of the waveform segments occur at different points in time.

15 72. The method of 70 wherein the end points of the waveform segments occur at different points in time.

73. The method of claim 50, wherein the first paced signal is the most recent paced signal and the second paced signal is the paced signal prior to the first paced signal
20 having the best fit.